

Year 2 Report

DEVELOPMENT OF AN INTEGRATED NORTHERN HEMISPHERE SNOW AND ICE OPERATIONAL CLIMATE DATA RECORD

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Project Overview

This project is designed to: (1) develop mature Northern Hemisphere terrestrial snow and sea ice CDRs with known levels of uncertainty and with community-standard metadata; (2) assemble mature Northern Hemisphere terrestrial snow and sea ice data products into an integrated snow and ice CDR; and (3) provide the snow and ice CDRs in multiple grids, on multiple time steps, and in multiple formats for the research community, decision-makers, and stakeholders.

Throughout the project, we are seeking community feedback via an Advisory Council and through town hall meetings at the American Geophysical Union fall conference to ensure that our CDRs will meet community needs. The CDRs will be provided via the Rutgers Global Snow Lab web site (<http://climate.rutgers.edu/snowcover/>) on several time steps (daily through annual), in various grids (e.g., Equal-Area Scalable Earth, 1° x 1°), and in various formats (e.g., text, netCDF, flat binary) for access by the community. The CDRs will also be distributed to relevant national data centers. Upon completion of this project, the CDRs will begin the transition to operational production at a NOAA center by introducing production into the ongoing operations at the Rutgers' National Climatic Data Center's Applied Research Center

facility. Once production confidence is fully attained and all requisite data archives and metadata are completed, the final transfer of processing to a NOAA operational center will take place. At that point, our study team will be performing scientific data stewardship activities only. This project is dovetailing well with a related effort that is funded by the NASA MEaSUREs initiative. This SDS project has major foci associated with operational and community aspects of our integrated snow-ice CDR. Meanwhile the NASA effort is geared more to the research side of things and concentrates on our developed products, their integration and how our research-quality CDR aligns with the principles expressed in a recent NRC report. In other words, within the SDS project, we are developing the "framework for integrating the mature CDRs". For NASA, we mainly focus on putting together our own records, but for NOAA, we are explicitly trying to develop a framework to bring in other data records. Furthermore, within the SDS project we are developing "known levels of uncertainty and community-standard metadata"; this doesn't appear in the NASA project as an objective. Thus our NOAA effort focuses a bit more on the issue of error and uncertainty analysis.

Milestones for the second year of the project have been met or are in the process of being completed. These include: (1) collecting existing snow cover and melt onset data records, including metadata information; (2) communications have taken place with the Dr. Walt Meier on bringing in his SDS sea ice concentration product and archiving a combine snow and ice operational product at NSIDC; (3) an advisory committee has been established and the first meeting was held in December 2009; and (4) a special session on snow CDRs was held at the 2009 AGU Fall meeting. We also have begun to embark on efforts tied in with the general project goals. The following discusses efforts to date regarding microwave, visible and station snow products, the project web site, and the advisory group.

Visible mapping of snow extent

Following multiple years of effort, mainly under NOAA support, we have completed a reanalysis of the NOAA satellite-derived snow cover extent product that dates back to late 1966. This product has long been used in international assessments of climate variability and change, and in investigations regarding the role of snow cover in the climate system. Despite their proven climate utility, meteorological forecasting has been the driving force behind producing these maps. As such, changes (documented and undocumented) in mapping methodologies have occurred over time without a focus on their climatological continuity. Members of our team have kept a watchful eye on changes in this satellite environmental data record (EDR). From this EDR, we have developed a satellite snow cover extent (SCE) climate data record.

Among the mapping changes that had to be accounted for, with adjustments made when necessary, was a category called "patchy" cover, which was often charted during the 1970s and early 1980s. We determined that such areas had insufficient snow cover to be digitized as such, thus these cells were eliminated from the weekly maps. Another major change occurred in the late 1990s, when following a two-year test overlap period, the coarse weekly product was officially replaced with a daily Interactive Multisensor Snow (IMS) 24 km resolution product. Comparing the 1966-99 climatology and 1999-08 IMS climatology found mismatched cells in each month. So too were mismatched cells found during a weekly and proto-IMS dual mapping period from 1997-99. Where mismatched cells were found for both tests, they were removed or added from weekly maps from the 1966-99 era, to agree with IMS era mapping. The resultant

"fine tuning" of SCE primarily addressed the IMS conversion to weekly and inconsistencies in mountainous regions (such as the Himalayas) during specific months of the year. More information and publications regarding these changes are forthcoming. Figure 1 shows a comparison of annual snow extent means between the former EDR and new CDR products. The latter reports less snow extent, a function of the removal of earlier patchy cells and especially the reduction of extents over mountainous areas, where clearly the early, coarser product depicted too much cover. To only a very small extent do these adjustments influence previously published assessments of continental snow extent variability and change.

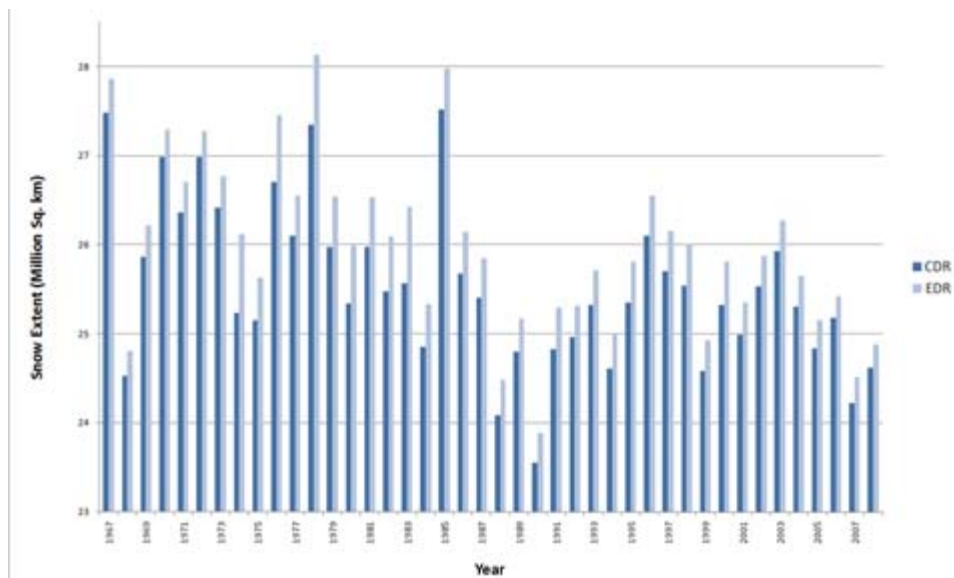


Figure 1. Annual Northern Hemisphere snow extent generated from the NOAA weekly environmental data record and the new NOAA weekly climate data record.

Station mapping of snow extent and depth

The 1x1 degree station product for North America has been completely updated through June 2009 and is available through the Rutgers Global Snow Lab. In conjunction with colleagues at the University of Georgia and the University of Delaware, we are examining the product in detail for effects of changes in the number of available stations. Daily station data for Eurasia, except China, has been examined from 1973-2008 for possible creation of a Eurasian version of this product. We have made contacts in the Chinese Meteorological Agency, National Climate Center, to attempt to acquire additional Chinese data.

We have recently begun working with Tom Mote at the University of Georgia on a project that is using the station products to assess the stability of the Rutgers/NOAA visible product. Preliminary results suggest a close agreement between the estimation of snow covered ground over the United States and southern Canada. However this relationship is not as strong in the

mountainous west and is somewhat weaker earlier in the satellite record than in the past few decades (both pre and post IMS mapping).

Ongoing Efforts to Generate an Integrated CDR

Efforts have begun to merge the NOAA visible CDR with other visible and microwave satellite and station-observed estimates of extent and depth over Northern Hemisphere lands, as well as with CDRs being developed for snow melt atop Arctic sea ice and ultimately, with Tom Mote, the Greenland ice sheet. The main emphasis of the work we completed this year, was generating the sea ice concentration, sea ice melt onset date and snow cover extent products into the same GIS format. In addition to the sea ice and snow cover parameters, atmospheric data from the Re-Analysis II project were also put into the same GIS format. Figure 2 shows a merger of snow and ice extent products during the week with the most extensive season snow cover during the 1992/93 winter.

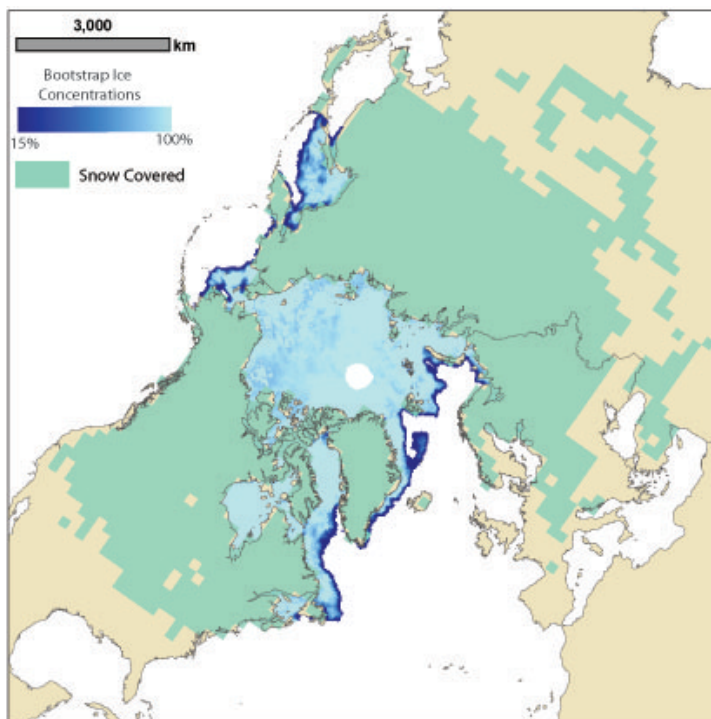


Figure 2. Combined snow and sea ice map. Snow extent is from the February 22-28, 1993 weekly map and Bootstrap sea ice concentration is for February 22, 1993

Figure 3 exemplifies our next step toward integrating cryosphere and atmospheric observations. and ice extent, snow melt on ice and re-analysis observations. This late May composite depicts the extent of snow on land, sea ice concentration, areas of previous and ongoing snow melt atop sea ice, maximum temperature at the 925 hPa level and surface pressure.

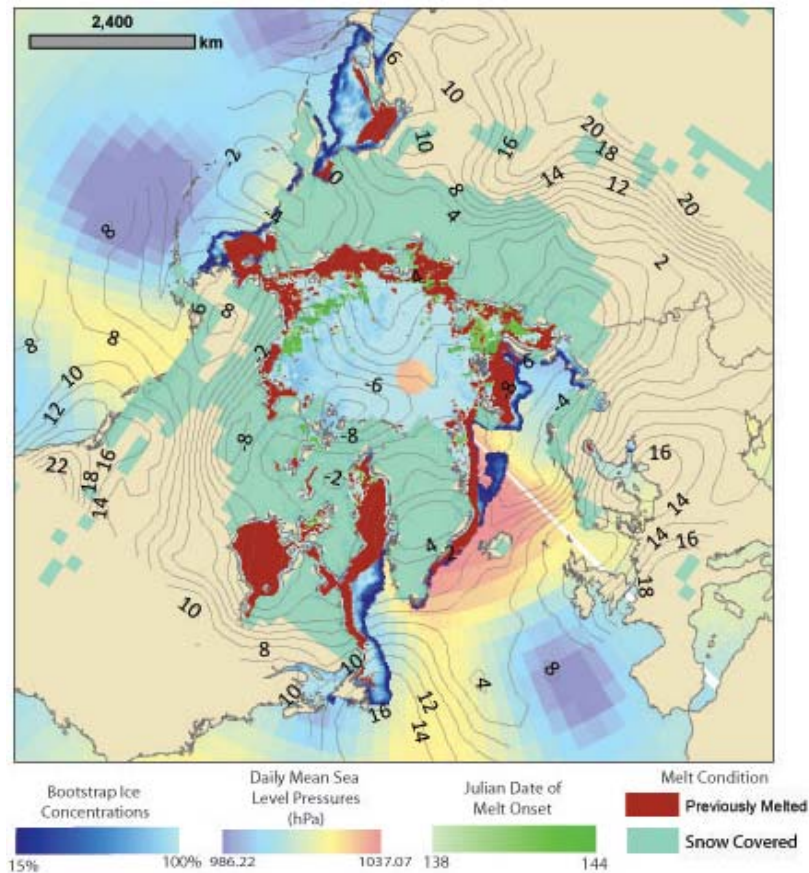


Figure 3. Comprehensive map containing Bootstrap sea ice concentration, locations where melt atop sea ice has previously commenced, sea level pressure and 925 hPa maximum daily temperatures on May 24, 1993. Continental snow extent and the mean Julian date of melt onset atop sea ice, during the week of May 18-24, 1993 are also shown.

We have begun to analyze linkages between surface and atmospheric conditions using the cryospheric and atmospheric products. Just examining snow and ice extents, figure 4 depicts June monthly normalized anomalies of each for three different sectors of the Arctic (swaths running from land into the basin) from 1979-2007. It is too early to recognize relationships, or the lack thereof amongst these two variables. The value of these analyses as they relate to our NOAA SDS effort is their utility in evaluating our cryospheric CDR products.

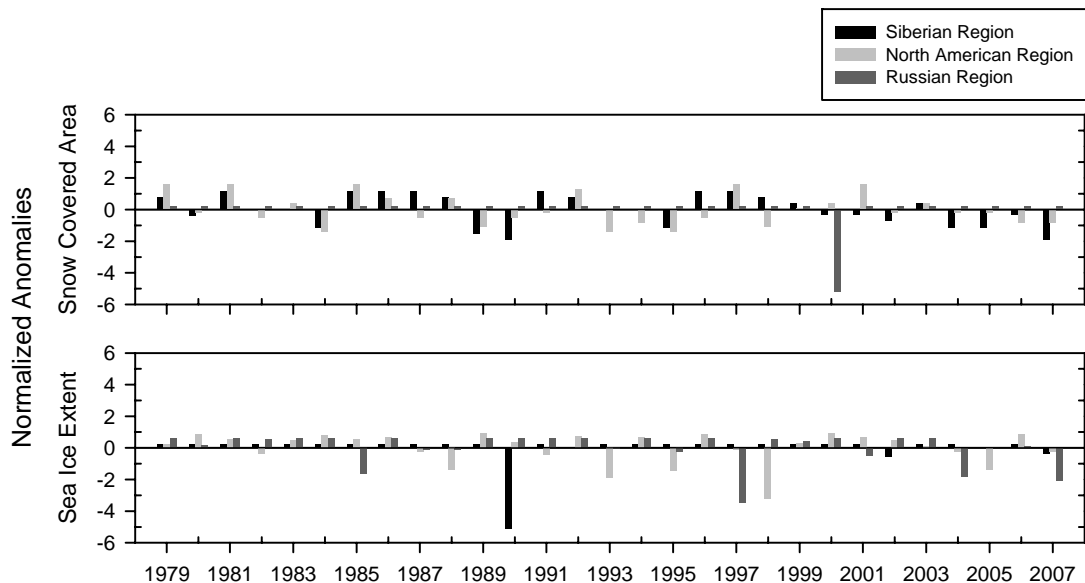


Figure 4. Normalized anomalies of June snow covered area and sea ice extent for the Siberian, North American, and Russian Regions (1979-2007).

Sea ice

Two data sets produced at the University of Colorado provide important project background information on sea ice motion and sea ice age. The production of ice motion fields relies on satellite data from drifting buoys, and passive microwave and AVHRR imagery. These data are then merged into single vector fields. These drift vectors are then used to track individual ice parcels. The result is a weekly time series of ice age, with age defined in terms of weeks since formation for first-year ice, and as age in years for different age classes of multiyear ice.

These data are updated through February 2009, and provide daily ice motion fields and weekly ice age for 1979 onward. The data sets continue to be archived and distributed from the University of Colorado, with a variety of derived products generated, included animations, plots and statistical summaries. The products were supplied to 16 individuals and groups in 2009. While the primary uses continue to be for arctic climate studies (for example, former Vice President Al Gore has included an animation of the age data in his climate change presentation), the data sets are also being used increasingly for a wider range of applications. For example, a researcher at Johns Hopkins is using the ice motion data to determine the trajectories of driftwood originating from river outflows. The age data are contributing to the assessment of shipping risk in the Beaufort Sea (U.S. Coast Guard), and for possible effects on marine mammal surveys near Barrow, Alaska. Of note is the use of the motion and age fields for flight planning during a NASA-sponsored unmanned aircraft systems (UAS) project carried out from Svalbard, Norway, and as input to flight planning for NASA IceBridge flights in 2010.

Colorado team members are also involved with obtaining and re-gridding sea surface temperature data for the Arctic. These latter data sets include NOAA optimally interpolated AVHRR SSTs, AVHRR Ocean Pathfinder SSTs, NCEP/NCAR reanalyses, and blended AMSR-E/MODIS SSTs.

Microwave mapping of continental snow extent

This work is not being supported directly by this grant. It is being performed by Tom Mote at the University of Georgia, as a continuation of an earlier NOAA collaborative effort with Robinson and as part of Mote's current participation on our complementary NASA MEaSUREs project team. This will be part of our SDS project historical database, and, like other "external" datasets evaluated during this project, will likely be incorporated into operational product development. The effort regarding the development of terrestrial snow cover TCDRs from microwave data involves: (1) vicarious calibration of the microwave terrestrial snow candidate TCDRs to existing in situ records, particularly the existing snow depth station data, (2) calibration of the microwave terrestrial snow candidate TCDRs to the visible satellite record, and (3) assessment of the relative differences in the AMSR and SSM/I satellite terrestrial snow candidate TCDRs. The comparison (currently 1992-2005) to in situ records involves frequency maps of differences and summary statistics between a gridded North American snow product from in situ data and the passive microwave products, as described in the project proposal. Examples of these difference maps are available on the Rutgers Global Snow Lab web site. Comparisons between the in situ and microwave snow depth are also being done in conjunction with ongoing work by S. Quiring (Texas A&M). Additionally, a similar comparison has been made between the microwave product and a 1° latitude by 1° longitude version of the NOAA weekly charts. Examples of these comparison maps are also available on the GSL web site. Updates of the SSM/I and AMSR based terrestrial snow candidate TCDRs have been produced through summer 2008. Sets of frequency maps of differences and summary statistics are being produced, but are not yet complete. Additional cross-validation will be required as NSIDC transitions from the use of the SSM/I F-13 satellite to other satellites.

Project web site

At this time, the focus of our project web site is on the NOAA snow product. We have also posted North American microwave-derived snow extent maps, North American station-derived snow extent maps, and some preliminary assessments of agreement/disagreement amongst the visible, microwave and station mapping of North American extent.

An international array of individuals maintains an interest in the databases and derived information. For the vast majority, a visit to the project website (<http://climate.rutgers.edu/snowcover>) suffices to meet their needs. In 2009, 23,594 individuals visited the site at least once (2008 saw 15,595 visits). Visitors clearly found the site useful, as there were 14,128 returning visitors over the course of the year (11,791 in 2008). January 2009 saw a 92% increase in visits over 2008, while December 2009 was second with a 71% increase over 2008.

As also seen in 2008, visits in 2009 came from 102 countries, with the top ten from greatest to least including the U.S., Russia, United Kingdom, Netherlands, Italy, Sweden, Canada, France, Spain, Germany (same as in 2008). 51% of the visitors came directly to the site, 36% arrived from a referring site, indicating a number of other websites contain a link to our site. The remaining 14% found the site through search engines.

For those seeking further information concerning the data or wishing to obtain all or portions of the gridded databases, individual consultations occur via phone or email and data. Most often these involve making all or portions of a database, including metadata, available for the customer to download. Follow up interactions often occur. In 2008, we provided data to 27 individuals, and already in 2009 seven requests have been or are in the process of being satisfied. Recent contacts have been primarily from the international academic community, although the USGS, USDOE, NASA, NCEP, NCAR and Meteo France from the government sector and three private firms also received data in 2008. Five requested the station product, the remainder sought one of our gridded satellite products.

With the ongoing updating of databases currently found on the site and the additional population of the site with the many single-source and blended CDRs being developed over the course of this project, we expect web site activity to continually increase. So too, do we expect increased interaction with those seeking consultation regarding the products.

Project advisory committee

We are pleased that the following excellent cryospheric scientists have agreed to lend their diverse knowledge and experience to our project as members of an advisory committee.

Dr. Jesse Cherry, University of Alaska, Fairbanks

Dr. Chris Derksen, Environment Canada

Dr. Gavin Gong, Columbia University

Dr. Walt Meier, National Snow and Ice Data Center, University of Colorado

Dr. Marc Stieglitz, Georgia Tech University

Dr. Daqing Yang, University of Alaska, Fairbanks and WMO Climate and Director, Cryosphere (CliC) Project Office, Tromso, Norway

We have conferred with various committee members at times during the past year. This included a meeting at the 2009 AGU Fall Meeting, where all committee members and project co-Is participated in the meeting in person or over a phone link. Further interactions will continue during the coming year. This includes the exchange of sea ice data with Dr. Meier.

Other synergistic activities

For the second consecutive year we put together a special session on Cryospheric Climate Data Records at the fall 2009 American Geophysical Union meeting.

Anderson chairs the PoDAG committee. In the process he is learning more about the process of submitting data sets into the NSIDC data archive.

Robinson contributed to the State of the Climate reports for 2007, 2008 and 2009 that are published in the *Bulletin of the American Meteorological Society*.

Anderson was an invitee/participant in the National Academy of Sciences Polar Research Board, “Sea Ice Information – Challenges and Opportunities” session.

Robinson has become a member of the National Academy of Sciences Climate Research Committee (NAS’s lead climate advisory committee). He continues participating on NOAA’s Climate Working Group (NOAA’s lead climate advisory committee).

Publications and Presentations

Since the project’s inception, there have been a number of papers published or submitted by team members that employ data from the SDS project datasets or are related to cryospheric data records. One master’s thesis has used project data. Numerous project-related presentations (most with accompanying abstracts) have been made as well.

Publications

- Doesken, N.J. and D.A. Robinson (2009) The challenge of snow measurements. *Historical Climate Variability and Impacts in the United States* (eds. Dupigny-Giroux and Mock) . Springer Publishing Co., NY, 251-274.
- Drobot, S., C. Fowler and J. Maslanik (2009) “Sea Ice Outlook” forecasts and reports. *Study for Environmental Arctic Change*.
- Ghatak, D., A. Frei, G. Gong, J. Stroeve and D. Robinson. Early indications of a climatic change signal in Siberian snow cover, amplified by Arctic sea ice loss. *Journal of Geophysical Research* (submitted).
- Gilman, J.B. et al. Surface ozone variability and halogen oxidation in the springtime throughout the Arctic and sub-Arctic. *Atmospheric Chemistry and Physics* (submitted).
- Maslanik, J.A. (2009) Sea, Water, Ice and Permafrost in the Arctic (SWIPA), Arctic Council summary report, contributing author: “Sea Ice Extent” chapter.
- Persson, P. O. G., E. L. Andreas, J-W. Bao, C. W. Fairall, A. A. Grachev, P. S. Guest and J. Maslanik. Determining wintertime heterogeneous pack ice characteristics and their impact on the aggregate atmospheric surface flux. *Journal of Geophysical Research* (submitted).
- Persson, P. O. G., E. L. Andreas, C. W. Fairall, A. A. Grachev, P. S. Guest and J. Maslanik (2008) Effect of surface heterogeneity on energy fluxes during the SHEBA winter. Paper 13B.5, Abstracts, Boundary-Layer and Turbulence Conference, Stockholm, Sweden.
- Pfirman, S., Tremblay, B., and Fowler, C. (2009) Going with the Floe? *American Scientist*, 97, 484-493.
- Tschudi, M.A., C. Fowler, J.A. Maslanik and J. Stroeve (2010) Tracking the movement and changing surface characteristics of Arctic sea ice (in press).

Choi, G., D.A. Robinson and S. Kang. Changing Northern Hemisphere snow seasons. *Journal of Climate*, 23 (accepted).

Abstracts/Presentations (all abstracts were presented at the meetings listed)

- Anderson, M.R., S. Drobot and A. Molthan (2008) Passive microwave bad scans and the importance of satellite data version numbers, *Abstracts: 2008 American Geophysical Union Fall Meeting*, San Francisco, CA.
- Bliss, A.C. and M.R. Anderson (2009) GIS as a comprehensive visualization tool for the Arctic cryosphere. *Abstracts: 2009 American Geophysical Union Fall Meeting*, San Francisco, CA.
- Choi, G., D.A. Robinson and S. Kang (2009) Changes in Northern Hemisphere vegetation and carbon dioxide seasons. *Abstracts: 2009 American Geophysical Union Fall Meeting*. San Francisco, CA.
- Choi, G., D.A. Robinson and W-T Kwon (2009) Recent changes in the Northern Hemisphere circumpolar vortex. *Abstracts: Association of American Geographers Annual Meeting*. Las Vegas, NV.
- Crocker, R.I., J. Maslanik, John Adler, S. Palo, C. Fowler, U. Herzfeld, M. Fladeland, B. Weatherhead and M. Angier (2009) Performance assessment of a small LIDAR altimeter deployed on unmanned aircraft for glacier and sea ice surface topography profiling. *Abstracts: 2009 American Geophysical Union Fall Meeting*, San Francisco, CA.
- Drobot, S.D., J.A. Maslanik, W. Emery, B. Blazey and C. Fowler (2008) Spatial and temporal trends in Arctic temperature climate data records. *Abstracts: 2008 American Geophysical Union Fall Meeting*. San Francisco, CA.
- Drobot, S.D., J.A. Maslanik, W. Emery, B. Blazey and C. Fowler (2009) Spatial and temporal trends in Arctic temperature climate data records. Annual Meeting of the American Meteorological Society, Phoenix, AZ.
- Ghatak, D., A. Frei, G. Gong, J.C. Strove and D.A. Robinson (2009) Interaction between Northern hemisphere snow and preceding summer Arctic sea ice. *Abstracts: 2009 American Geophysical Union Fall Meeting*. San Francisco, CA.
- Maslanik, J.A., R.I. Crocker¹, K. Wegrzyn, C. Fowler, U. Herzfeld, D. Long, R. Kwok, M. Fladeland, P. Bui, and G. Bland (2009) Characterization of Fram Strait sea ice conditions using the NASA SIERRA unmanned aircraft system. *Abstracts: 2009 American Geophysical Union Fall Meeting*, San Francisco, CA.
- Robinson, D.A. (2008) Historical evaluation of NOAA snow maps. Snow Mapping Workshop, National Ice Center, Suitland, MD.
- Robinson, D.A. (2008) Elements of successful cryospheric climate data records. *Abstracts: 2009 American Geophysical Union Fall Meeting*, San Francisco, CA.
- Robinson, D.A. and T. Estilow (2008) A Northern Hemisphere snow extent climate data record. *Abstracts: 2008 American Geophysical Union Fall Meeting*, San Francisco, CA.
- Robinson, D.A. and T.W. Estilow (2010) Northern Hemisphere snow cover extent during the satellite era. *Abstracts: 22nd Symposium on Climate Variability and Change*, American Meteorological Society, Atlanta, GA.

- Robinson, D.A. and T. Estilow (2009) A Northern Hemisphere Snow Extent Climate Data Record. *Abstracts: 2009 American Geophysical Union Fall Meeting*. San Francisco, CA.
- Robinson, D.A., M.R. Anderson, D.K. Hall, T.L. Mote, C. Fowler, J.A. Maslanik and S. Drobot (2009) Development of Northern Hemisphere snow extent Earth System Data Records. *Abstracts: 2009 American Geophysical Union Fall Meeting*. San Francisco, CA.
- Stroeve, J.C., A. Frei, G. Gong, D. Ghatak, D.A. Robinson and D. Kindig (2009) Precipitation impacts of a shrinking Arctic sea ice cover. *Abstracts: 2009 American Geophysical Union Fall Meeting*, San Francisco, CA.
- Zaugg, E., D. Long, M. Edwards, M. Fladeland, R. Kolyer, R. Crocker, J. Maslanik and U. Herzfeld (2009) Combining data from a small SAR on an unmanned aircraft with satellite observations: The microASAR on the NASA SIERRA UAS for the Characterization of Arctic Sea Ice Experiment (CASIE), CEOS SAR 2009: CEOS SAR Workshop on Calibration and Validation.